NOTE

FIRST-YEAR RESPONSE TO FIRE BY THE CALIFORNIA GRASSLAND PERENNIAL, *DODECATHEON CLEVELANDII* SSP. *PATULUM* (PRIMULACEAE).—Robert Schlising, Department of Biological Sciences, Gregory Treber, Department of Agriculture, and Caroline Warren, Department of Biological Sciences, California State University, Chico, CA 95929.

Much of the literature on North American grasslands and fire deals with middle portions of the continent, centering on the Great Plains (Daubenmire, Advances in Ecological Research 5:209–266, 1968; Vogl *in* Kozlowski and Ahlgren, Fire and Ecosystems, Academic Press, 1974; Risser *in* Chabot and Mooney, Physiological ecology of North American plant communities, Chapman and Hall, 1985; Collins and Wallace, Fire in North American tallgrass prairies, University of Oklahoma Press, 1990; Coupland, Natural grasslands, Elsevier, 1992). Published information specifically on plants and fires for the annual grasslands of California is scarce (Huenneke and Mooney, Grassland structure and function. California annual grasslands, Kluwer Academic Publishers, 1989; Heady et al. *in* Coupland 1992), and work on this region mainly emphasizes vegetation responses to fires, such as changes in species composition, plant densities, and production. Although Keeley (*in* Mooney et al., USDA, Forest Service, GTR WO-26, 1981) has noted that California's mediterranean climate annual grasslands represent one of the most fire-resilient of all herbaceous plant communities, there is suprisingly little detailed information on responses to fire—especially on reproductive responses—by individual species in these grasslands.

For grasslands in general, individual species of both grasses and forbs are known that show increased reproductive growth, including increases in flowering and seed production after fires (Daubenmire 1968; Vogl 1974; Risser 1985), and Heady (Proceedings of the Tall Timbers Fire Ecology Conference 12:97–107, 1973) has suggested that aboriginal people may have set fires to stimulate flower, fruit, and seed production in grasslands. But such increased fruit and seed production after burns is very poorly documented for California species, and only a few studies lend strong support for increased reproduction after burns. In one early study specifically for Californian grasslands, Hervey (Journal of Range Management 2:116–121, 1949) reported both increases and reductions in height and in "yield" for several naturalized forbs and grasses measured in adjacent burned and unburned areas. While there is much research on the widespread native perennial bunchgrass *Nasella* (*Stipa*) *pulchra,* there is little published on increased reproductivity for this plant in burned areas (although increased seed weight was noted by George et al., Journal of Range Management 45:436–440, 1992). A study by Hunter (Madroño 33:305–307, 1986) has documented significantly higher fruit numbers per plant after a burn for the native annual forb, *Sidalcea calycosa* (Malvaceae), that grows in swales and shallow pools in annual grasslands. Mitchelson (M.S. thesis, California State University, Chico, 1993) has documented a highly significant increase in fruits per plant for the perennial geophyte *Zigadenus fremontii* (Liliaceae) growing in a burned grassland in the northern Sacramento Valley. Our study was initiated to investigate reproductive responses to fire by a non-geophytic perennial growing in these same grasslands.

Dodecation clevelandii E. Greene ssp. *patulum* (E. Greene) H. J. Thompson, the lowland shooting star, is native and widespread in cismontane California—especially in and about the Central Valley (Hickman, The Jepson Manual: Higher Plants of California, University of California Press, 1993; Thompson, Contributions of the Dudley Herbarium 4:73–154, 1953). This hemicryptophyte grows a new rosette of basal leaves from a shallowly-buried caudex, following the resumption of rains each fall. By February in the northern Sacramento Valley, the plants produce solitary

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scapes with several nodding, whitish, black-tipped flowers. Flowering is usually completed by mid-March. The leaves wither soon after flowering, but the green scape and young capsules may continue to supply photosynthate to the developing seeds. While exceedingly common and obvious in the grasslands before most associated species have completed much aboveground growth, this perennial essentially disappears when most grasses and forbs mature and become reproductive in April. The fruits of the shooting star ripen in late April here, but the dried scapes and their fruits can be found all summer.

This study was carried out at the Vina Plains Preserve, a region of annual grassland and vernal pools owned by the California Nature Conservancy, in southernmost Tehama County about 19 km north of Chico. The area in which this study was conducted is in sections 28 and 33, T24N, R1W (Richardson Springs 7.5′ USGS quadrangle map), where the elevation is about 65 m above sea level. The region has the characteristic mediterranean climate of central California, with cool, moist winters followed by very hot and dry summers. Broyles (M.A. thesis, California State University, Chico, 1983; Madroño 34:209–227, 1987) has listed 287 species of vascular plants in the flora of the preserve, of which 90 (33%) are introduced species and of which 50 (17%) are native and introduced grasses. Topography here consists of very gently rolling terrain, with only a few meters change in elevation. Soils of the study area are well-drained, and belong to the Tuscan Series (Soil Survey of Tehama County, California, USDA, 1967).

On 15 July 1993, a fire that started accidentally at Highway 99 to the west, spread eastward across the Preserve. The area chosen for the present study within this burn had not been submitted to fire-suppression equipment or chemicals. Precipitation and mean temperatures for the fall/winter months following this fire, and through the spring months of this study are based on weather data taken at Orland, about 18.5 km southwest of the Preserve and the nearest site maintaining complete weather records (Climatological Data: California, National Oceanic and Atmospheric Administration, 1993, 1994). These data show that the amount of rainfall varied considerably from the longterm monthly mean for most months during the first growing season following the fire. Most months, except February, had less than normal precipitation: November, −45 mm (below mean); December, −36 mm; January, −23 mm; February, +71 mm (above mean); March, −71 mm; and April, −12 mm. Monthly temperatures in degrees C were above longterm means for all months except February (November, +0.6; December, +0.3; January, +2.5; February, −0.9; March, +2.3; and April, +1.5).

The major hypothesis was that there would be no difference in first year growth (size) and reproduction of these established perennial plants growing in the burned and in the adjacent unburned areas. To test this, 10 parallel 30-m belt transects 1-m wide, were established on two adjacent well-drained areas. Half of each transect occurred within the area burned in 1993, and the other half extended into area not burned. For each transect, the middle 10 m (5 m in burned and 5 m in unburned) was kept as the "burn line buffer zone" and was not sampled; only the outer 10 m in each transect was used. Each of the resulting 10 m × 1 m transects, both in burned and in unburned areas, was divided into gridded 1-m-squares, where random numbers were used to sample 1 plant per square meter—for a total of 100 burned-area plants and 100 unburned-area plants.

Transects were set up on 28 February 1994, when all rosettes were at full size, but the plants were not yet in full flower. Plants were sampled only if the beginning of a flower scape was visible (that is, only plants flowering in 1994 were to be sampled). The basal rosettes of the 200 sampled plants were assessed in the field by measuring the rosette diameter; these plants were then marked with stringed tags. On 7 March, flowers were collected immediately adjacent to sample areas (1 flower from each of 3 plants per transect) in both burned and unburned areas, for laboratory determination of ovule number per ovary.

On 25 April, tagged scapes (with ripe fruits) were harvested by cutting the scape

TABLE 1. VEGETATIVE AND REPRODUCTIVE FEATURES SHOWN BY PLANTS OF *DODECATHEON CLEVELANDII* SSP. *PATULUM* THE SPRING AFTER A SUMMER FIRE, IN ADJACENT BURNED VS. UNBURNED AREAS OF ANNUAL GRASSLAND. Measurements are given as mean ± SE (with sample size in parentheses). Student's t-tests indicate that means for both rosette area and scape height are highly significantly different ($P < 0.0001$). Means for other features are not significantly different at the 95% level. [1] Lower sample numbers reflect scape destruction by rodents. [2] Fruits per plant based on all plants with 0–6 fruits, including fruits with 0 seeds. [3] Seeds per plant and seeds per fruit based on fruits with 0–62 seeds. [4] Seed weights based only on plants that produced 1 or more seeds.

Feature	Burned area	Unburned area
Rosette area (sq cm)	25.8 ± 1.2 (100)	37.5 ± 1.8 (100)
Scape height (cm)[1]	4.8 ± 0.2 (83)	5.8 ± 0.2 (87)
Fruits per plant[2]	1.2 ± 0.1 (83)	1.3 ± 0.1 (87)
Aborted flowers per plant	1.8 ± 0.1 (83)	1.6 ± 0.1 (87)
Plants with fruit	51	58
Seeds per plant[3]	25.8 ± 3.4 (51)	25.9 ± 4.3 (58)
Seeds per fruit[3]	13.4 ± 1.3 (98)	13.2 ± 1.4 (114)
Ovules per ovary	134.6 ± 6.7 (30)	135.2 ± 5.3 (29)
Ovule/seed ratio	10.8	9.9
Seed wt per plant (mg)[4]	20.1 ± 2.5 (38)	18.9 ± 2.9 (45)
Seed weight (mg)[4]	0.6 ± 0.03 (38)	0.5 ± 0.03 (45)

as close to the rosette as possible. These scapes were assessed in the laboratory for the following parameters: scape height (to the nearest 0.1 cm, measured to the point of the lowest fruiting pedicel); number of developed fruits; number of additional (aborted) flowers that did not develop into fruits; and number of seeds per fruit. On 8 July, after over 10 weeks of air-drying, the seeds for each fruit were weighed on a Sartorius analytical balance. Statistical analyses were performed by checking for equality of variances and then doing the appropriate t-tests to compare means.

Measurements and calculations assessing first-year growth of the plants sampled are shown in Table 1. Measurements of leaf rosette diameter were used to calculate rosette area, a clearly vegetative (non-reproductive) parameter of the plants' growth. Means for rosette area and scape height are both highly significantly different in the burned vs. unburned areas. Means for the remaining (reproductive) parameters are not significantly different.

In general, plants show enhanced growth and increased reproduction after fires (Risser, 1985; Heady, Rangeland Management, McGraw Hill, 1975; Chapman and Crow, Bulletin of the Torrey Botanical Club 108:472–478, 1981; Anderson *in* Collins and Wallace 1990). But according to generalizations in the literature (e.g., Daubenmire 1968; Heady et al. 1992), grassland fires may have little effect on plant habitat; our data indicate that this may be true for the habitat of the shooting stars we studied. For instance, summer fires in the California annual grasslands tend to move through an area rapidly due to the fine fuels and extreme dryness, and burn at relatively cool temperatures. For these reasons, although there is some loss of nitrogen and sulphur during a fire, and the potential for either wind displacement of ash or leaching of nutrients exists, the overall effect on the soil chemistry may be minimal. Therefore, higher soil fertility and resulting enhanced growth of plants is not necessarily to be expected after a burn.

Larson and Duncan (Journal of Range Management 35:701–703, 1982) found no increases in herbage in a burned area the first year in their study at the San Joaquin Experimental Range NE of Fresno, and in the burned areas of our study at the Vina Plains the leaf rosettes were actually significantly smaller than in the adjacent unburned areas (Table 1). This is difficult to explain, but these size differences may be due to a combination of abiotic factors relating to litter removal by the fire. The unburned areas of our study, like most annual grassland sites in California, were covered by a considerable layer of mulch, and the differences in rosettes may be the result of factors such as moisture retention in soil, compaction of bare ground by raindrops, and light availability. The litter may have acted as a canopy that lowered light intensity (Evans and Young *in* Huenneke and Mooney 1989; Huenneke and Mooney *in* Huenneke and Mooney 1989; Menke *in* Huenneke and Mooney 1989) to the rosettes of the shooting stars. The plants may have responded to shading within the deep layer of dead plant material by producing larger leaves. Similarly, significantly taller scapes (Table 1) in heavy mulch may represent an etiolation-like response by the study plants. This mulch was thick at the study site due to above-normal precipitation during the growing season before the fire (NOAA 1993).

In contrast to these two essentially vegetative parameters, the reproductive features measured in our study showed no significant differences for burned vs. unburned grassland habitat (Table 1). Although Risser (1985) notes a general increase in flowering and seeding for plants in recently burned areas, Wallace (*in* Collins and Wallace 1990) states in her epilogue in *Fire in North American Tallgrass Prairies* that fire influences on sexual reproduction are as varied as the plant species being studied. Several other studies have demonstrated variation in reproductive response. Another species of shooting star (*Dodecatheon meadia*) studied in the tallgrass prairie documented more flowers per plant in burned areas compared with unburned (Glenn-Lewin et al. *in* Collins and Wallace 1990). For the few species studied in California, observations on common geophytes, such as several species of *Calochortus* and *Dichelostemma pulchella* (Muller et al., Bulletin of the Torrey Botanical Club 95:225–231, 1968), and detailed research on *Zigadenus fremontii* (Mitchelson 1993), show marked increases in flowering and fruiting after fire. Fossum (M.S. thesis, University of California, Davis, 1990) studied flowering and seed weights of the hemicryptophytic grass *Nassella pulchra,* and found that the first-year fire response showed a 55% decrease in seed number, but a 12% increase in seed weight. Our data, indicating neither a positive or negative effect on reproduction in *D. clevelandii* by fire, provide a valuable addition to the very sparse literature on individual grassland species in California.

These data on the lowland shooting star were collected in a year with all months except February receiving lower than normal rainfall and higher than normal temperatures. Year-to-year total precipitation in California's mediterranean grasslands is extremely variable, and whether these drier and warmer conditions affected the plants is not known. The period of greatest precipitation did coincide with early flowering (February received 71 mm above the long-term mean), and soil moisture conditions appeared to be near field capacity during flowering and fruiting. Reproductive success (Table 1) on *both* sites seemed low (with a mean of only about 13 seeds per fruit in both burned and unburned areas, and an ovule/seed ratio of only 10.8 and 9.9).

All of the parameters measured concerning flowering, fruiting, and seeding support the original hypothesis that there would be no difference in first-year growth and reproduction in *Dodecatheon clevelandii* ssp. *patulum.* But both rosette area and scape height in this perennial forb were found to be larger in unburned grassland habitat here, strongly suggesting a non-beneficial influence from fire, at least concerning plant size.

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